INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0533

ALARA™ 1146 Strippable Coating

Deactivation and Decommissioning
Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

April 2000

ALARA™ 1146 Strippable Coating

OST/TMS ID 2314

Deactivation and Decommissioning
Focus Area

Demonstrated at
321-M Fuel Fabrication Facility
Large-Scale Demonstration and Deployment Project
Savannah River Site
Aiken, South Carolina

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

TABLE OF CONTENTS

SECTION 1
SUMMARY

Strippable or temporary coatings are alternative technologies for decontamination that effectively reduce loose contamination at low cost. These coatings have become a viable option during the decontamination and decommissioning (D&D) of both U.S. Department of Energy (DOE) and commercial nuclear facilities to remove or fix loose contamination on both vertical and horizontal surfaces.

In a project funded by DOE's Office of Science and Technology (OST), a side-by-side assessment of six strippable coatings was performed at the Savannah River Site (SRS) by SRS and the Hemispheric Center for Environmental Technology at Florida International University (FIU-HCET). Each coating was evaluated for ease of application and removal, decontamination factors (DF), durability and cost. A summary of the results are presented in Appendix B. The decision was made, based on the results of that assessment, to demonstrate, at full-scale, the ALARA™ 1146 strippable coating as part of the SRS Large-Scale Demonstration and Deployment Project (LSDDP).

The ALARA™ 1146 strippable coating successfully removed transferable (surface) contamination from multiple surfaces (metal and concrete) with an average DF for alpha contamination of 6.68 (85.0% removal). Beta contamination was removed with an average DF of 5.55 (82.0% removal). Productivity is about the same for both technologies. The rate of decontamination was about 135 ft^2/hr. Unit costs for the ALARA™ 1146 are \$4.85/ft^2 versus \$2.74/ft^2 for the baseline steam vacuum cleaning technology (excluding mobilization and demobilization). However, ALARA™ 1146 provides a total cost savings of 33%, compared to the baseline technology, for relatively smaller jobs. For jobs less than 3,408 ft^2, the strippable coating is more cost effective, while the baseline technology is more cost effective for jobs in which more than 3,408 ft^2 is to be decontaminated.

Technology Summary

ALARA™ 1146 is a water-borne vinyl strippable coating that is free of solvents and toxic materials. It is used to mechanically lock radionuclides into the coating and upon stripping, remove them from substrates. The main characteristics of this coating include rapid application and removal, reduced waste volumes, immobilization of surface contaminants, and reduction of surface contamination. ALARA™ 1146 has been used to decontaminate reactor cavities during outages at commercial nuclear facilities. This strippable coating has a mild odor, does not contain chlorides, and comes in two colors, yellow and blue. The blue is for routine use, while the yellow has been certified for use in reactor outages.

Figure 1. ALARA™ 1146 being removed from wall.

Problem Addressed

Residual contamination is often non-adherent and can lead to an airborne activity problem. In addition, for D&D projects there is no guaranteed ability to process liquid waste such as in the Savannah River Site (SRS) 321-M facility. Any liquid wastes would have to be collected and transported to another location for processing. Consequently, it is important to eliminate such wastes or keep them to a minimum. Therefore, there is a consequent need for a technology to remove surface contamination without producing liquid secondary waste.

How It Works

Applied over a contaminated surface, ALARA™ 1146 attracts and binds surface contaminants. The coating migrates into the micro-voids of the surface to contact contaminants. Upon cure, the product mechanically locks the contaminants into a polymer matrix. Removal of the film decontaminates the substrate and produces a solid waste.

Potential Markets

ALARA™ 1146 is well-suited to any decontamination project where the objective is to remove surface contamination including radionuclides, dirt, PCBs, asbestos particles, and loose paint. Typical applications are for bare and painted concrete, wood, carbon steel, stainless steel, plastic, and insulation. **It is best for projects where the generation of liquid wastes is not desirable.**

Advantages over the Baseline

The baseline technology for the 321-M Deactivation Project is a steam vacuum cleaning technology. This system uses superheated pressurized water to remove contaminants from floors and walls. The spray head incorporates a shrouded vacuum pickup to remove water and contaminants from the surface being cleaned. The ALARA™ 1146 strippable coating reduces or eliminates the quantity of liquid waste as compared to the baseline technology.

Demonstration Summary

This report covers the period of May 11 – May 18, 1999, when the ALARA™ 1146 strippable coating was demonstrated as part of the Savannah River Site Large-Scale Demonstration and Deployment Project (LSDDP). The product vendor, Williams Power Corporation, provided the spray application equipment and operational direction during the demonstration.

The purpose of the demonstration was to evaluate the effectiveness, efficiency, and cost of the ALARA™ 1146 strippable coating as an alternative to the baseline, steam vacuum cleaning technology, for the removal of surface contamination from metal and concrete surfaces. Radiological surveys, for transferable contamination, were performed both before the strippable coating was applied and after the coating was removed. The purpose of these surveys was to determine the level of decontamination achieved by the ALARA™ 1146.

Demonstration Site Description

The 321-M Fuel Fabrication Facility at SRS was built in the 1950s to manufacture fuel tubes for the SRS production reactors. The manufacturing involved precise weigh-out of aluminum and enriched uranium, melting them together into alloy, extruding the alloy into tubes, and various steps involving machining, welding, and chemical cleaning. As a consequence, about 9,000 square feet inside the facility have been contaminated with Highly Enriched Uranium (HEU). Contamination is present on floors and walls, in the overheads, and on the surfaces of storage racks and carts used to move material around. It is also present on the outside surfaces of equipment enclosures and both inside and outside hoods and gloveboxes. The facility has no liquid waste processing system in service requiring all liquid waste to be collected and transported to a second facility for processing.

The demonstration of the ALARA™ 1146 strippable coating was performed in the following locations within the 321-M contaminated area:

- Machining Room – approximately 875 square feet (ft^2) of wall space and 300 ft^2 of floor area.
- Log Storage Room – approximately 150 ft^2 of wall area.
- Casting Room Cooling Hut – approximately 1500 ft^2 of wall, floor, and ceiling area.

The Machining Room and Log Storage Room walls are painted carbon steel, and the floors are concrete with an epoxy coating. The Casting Room Cooling Hut interior walls and ceiling are unpainted carbon steel, while the floor is concrete with an epoxy coating.

Key Results

The ALARA™ 1146 strippable coating was successfully demonstrated at the SRS 321-M facility with the following key results:

- The ALARA™ 1146 strippable coating successfully removed transferable (surface) contamination from multiple surfaces (metal and concrete) with an average decontamination factor for alpha contamination of 6.68 (85.0% removal). Beta contamination removed was an average DF of 5.55 (82.0% removal).

- Although use of the ALARA™ 1146 resulted in significant reduction in overall contamination in the demonstration areas; however, future work planned in the area made reduced postings impractical at the present time.

- No observable increase in airborne contamination was noted during the ALARA™ 1146 demonstration.

- ALARA™ 1146 strippable coating was easily applied using spray paint equipment. The cured coating was also easy to remove, coming off in large pieces.

- A minimum of liquid waste was generated (approximately six gallons of water) during the demonstration, which was used to clean the spray equipment after use.

- The unit cost per ft^2 is $4.89 for strippable coatings versus $2.74 for the steam vacuum cleaning technology (not including mobilization and demobilization). However, when comparing the total costs of the demonstrations, the strippable coating offers a 33% cost savings over the baseline technology for small jobs. For jobs greater than 3,408 ft^2 the baseline technology is more cost effective.

Regulatory Considerations

There are no regulatory permits required to use the ALARA™ 1146 strippable coating.

Commercial Availability

ALARA™ 1146 is fully developed and commercially available from Williams Power Corporation.

Future Plans

The ALARA™ 1146 strippable coating will be used on future D&D projects at SRS both as a decontamination technology and as a fixative.

Contacts

Technical

Jeffrey Lee, Westinghouse Savannah River Company, (803) 725-0652**;** jeffreyw.lee@srs.gov
Cecil May, Savannah River Technology Center, (803) 725-5813; cecil.may@srs.gov
T. J. McNamara, Williams Power Company, (410) 620-3373; mcnamara@wmsgrpintl.com

Management

Cecil May, Test Engineer, Savannah River Technology Center, (803) 725-5813; cecil.may@srs.gov
John Pierpoint, Project Manager, Westinghouse Savannah River Company, (803) 725-0649; john.pierpoint@srs.gov

Department of Energy

Martin Salazar, U.S. Department of Energy, Savannah River Operations Office; (803) 557-3617; martin.salazar@srs.gov
George Mishra, U.S. Department of Energy, Savannah River Operations Office; (803)725-7239; george.mishra@srs.gov
John Duda, National Energy Technology Laboratory, (304) 285-4217, john.duda@netl.doe.gov

Website

The 321-M LSDDP Internet address is **http://www.srs.gov/general/srtech/lstd/index.htm**

Licensing

No licensing or permitting activities were required to support this demonstration.

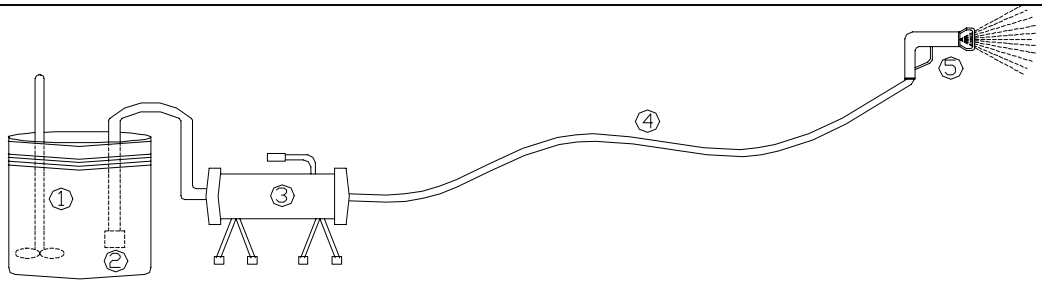
Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under “Publications.” The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for ALARA™ 1146 Strippable Coating is 2314.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

The ALARA™ 1146 strippable coating is a water-borne vinyl butyl, which can be sprayed, rolled, brushed, or pour squeegeed onto the surface to be decontaminated in the same manner as paint (see Figures 2 and 3). The vendor, however, recommends spray application for decontamination purposes. **The coating is free of solvents and toxic materials.** Applied over a contaminated surface, ALARA™ 1146 strippable coating migrates into micro-voids of the surface to contact and bind surface contaminants. Upon curing, the product mechanically locks the contaminants into a polymer matrix. Removal of the film decontaminates the surface and produces a solid waste. Removal of the strippable coating from the surface after curing involves stripping or pulling the coating away from the surface. To facilitate its removal, the coating can be scored into large sections with a sharp knife. The coating can be rolled as it is removed for ease of handling and to further trap any residual contamination on the surface of the coating. The ALARA™ 1146 can be applied to bare and painted concrete, wood, carbon and stainless steel, plastic, and insulation.



1. Mixer: Electric drill and stirrer used to mix the ALARA™ 1146 prior to and during application.
2. ALARA™ 1146: Container (1 or 5 gal) of liquid strippable coating.
3. Spray Equipment: Graco Ultra Plus 1500 Electric Airless Spray Applicator. Both the strippable coating and the spray applicator remained in an uncontaminated area during the demonstration.
4. Hose: 100 ft of ¼-in. inner diameter (ID) sleeved in plastic to prevent contamination.
5. Spray Gun: Graco Silver Plus Airless Spray Gun, 0.517 in. reversible tip, held 10 – 12 inches from surface.

Figure 2. Process diagram of ALARA™ 1146 application.

Figure 3. Application of ALARA™ 1146 strippable coating.

The baseline approach for removing surface contamination from the 321-M facility surfaces is the steam vacuum cleaning technology (Figure 4). This technology uses superheated pressurized water to remove contaminants from floors and walls. The superheated water flashes to steam when it impacts the surface. The hood of the steam vacuum cleaning head traps and collects dislodged contaminants, steam, and water droplets. The waste stream passes through a liquid separator, a demister, and a high efficiency particulate air (HEPA) filter that removes contaminants and discharges clean air to the atmosphere.

Figure 4. Photos of a steam vacuum cleaning technology.

For D&D projects, there is no guaranteed ability to process liquid waste, as in the 321-M facility at SRS. Therefore, the contaminated liquid waste generated by the steam vacuum cleaning technology must then be collected and transported to a second SRS facility for processing. The ALARA™ 1146 strippable coating was selected for demonstration at SRS because the coating, with entrapped contaminants, constitutes a solid waste, making disposal easier.

System Operation

An airless spray system with the following specifications is recommended for applying the ALARA™ 1146 strippable coating:

Pump Ratio:	30:1 (minimum)
GPM Output:	3.0 (minimum)
Hose:	3/8 – 1/2 in. ID
Tip Size:	0.021in. minimum
Output psi:	1800 – 2300
Electrical:	110 volts

Table 1, presented on the following page, summarizes the operational parameters of the ALARA™ 1146 strippable coating provided by the vendor.

Table 1. Operational parameters for ALARA™ 1146

Equipment Specifications and Operational Parameters	
Surface preparation	None required
Application conditions Normal Minimum Maximum	 70°F (21°C) at 50% RH 40°F (4°C) at 10% RH 90°F (32°C) at 85% RH
Recommended thickness Wet film Dry film	 45 – 50 mils (1125 – 1250 microns) 20 – 30 mils (500 – 750 microns)
Application equipment used for the demonstration	Graco Ultra Plus 1500 Electric Airless Sprayer Graco Silver Plus Airless Spray Gun, 0.517 Reversible Tip Two 50-ft, ¼-in. diameter hoses Electric mixer
Application instructions	Hold spray gun at a 45^{o} angle to surface and approximately 10 – 12 in. from surface. Move spray gun slowly (10 – 15 in./sec) across area.
Percentage overlap each pass	50%
Theoretical coverage (25 mils (625 microns) thickness)	26 ft^2/gal (0.6 m^2/l)
Number of gallons of ALARA™ 1146 used for the demonstration	70
Drying times [a] Set to touch Foot traffic Removal	 9 h 18 h 24 h
Manpower Skills and Training Requirements	
Work crew	Two to three full-time mechanics
Specialized skills	None required
Training	The vendor supplied training to the mechanics on the operation of the Graco airless spray applicator.
Potential Operational Concerns	
Operating	During spraying, the spray gun tip can get clogged and would have to be taken apart and cleaned. The use of a reversible tip minimizes this concern.
Safety/health	Airline respirators are recommended by the vendor to prevent inhalation of over-spray. Full-face respirators were required by SRS due to possible airborne contamination while spraying.
Environmental	Potential release of airborne radionuclides during strippable coating application. Strippable coatings may clog ventilation filters and spread into undesirable areas. The use of roughing filters and covering open areas is recommended.

[a] Based on 25 mils (625 microns) at 75°F (25°C) and 75% relative humidity (RH). Dry times can be minimized (to as low as 20 minutes for Removal) by increasing the air movement within the area.

SECTION 3
PERFORMANCE

Demonstration Plan

Demonstration Site Description

The demonstration of the ALARA™ 1146 was conducted according to the approved Westinghouse Savannah River Company, 321-M LSDDP Test Plan (WSRC, 1999). The demonstration of this alternative technology was performed at the 321-M Fuel Fabrication Facility at SRS. This facility was built in the 1950s to manufacture fuel tubes for the SRS production reactors. The facility covers approximately 62,000 ft^2 and contains casting, forging, extruding, and machining equipment that were used to produce uranium-aluminum fuel tubes. Approximately 9,000 ft^2 inside the facility have been contaminated with HEU.

Demonstration Objectives

The principal goal of the demonstration was to establish whether the ALARA™ 1146 strippable coating could safely and effectively remove loose contamination from various materials and surfaces, to document performance and cost data for strippable coatings, and to compare this data to the baseline technology. This determination would be based on the strippable coating's ability to achieve the following objectives:

- Reduce the generation of liquid waste relative to the baseline technology
- Remove surface contamination from multiple surfaces and materials
- Ease of application and removal.

Demonstration Boundaries

The ALARA™ 1146 strippable coating was demonstrated on painted and unpainted carbon steel and epoxy coated concrete. The coating is also capable of decontaminating other materials such as wood, plastic, and insulation; however, the product was not demonstrated on these substrates at the 321-M project. The ALARA™ 1146 can also be used to protect clean surfaces from becoming contaminated and can be left in place over long periods of time. These capabilities were demonstrated in the side-by-side comparison of multiple strippable coatings summarized in Appendix B.

Results

The following table describes the areas in the 321-M facility that were included in the ALARA™ 1146 demonstration:

Table 2. Demonstration areas and materials

Area	Painted Carbon Steel Walls	Epoxy Coated Concrete Floors	Unpainted Carbon Steel Walls and Ceiling
Machining Room	878 ft^2	330 ft^2	---
Log Storage Room (south and west walls)	132 ft^2	--	---
Casting Room Cooling Hut (inside hut – includes racks and/or shelves)	250 ft^2	525 ft^2	730 ft^2

The ALARA™ 1146 successfully demonstrated its ability to remove surface contamination from metal and concrete surfaces safely and effectively. Table 3 summarizes the decontamination results from the demonstration. Individual decontamination results can be found in Appendix C.

Table 3. Decontamination summary for ALARA™ 1146 by material

Material	Transferable alpha (α) contamination		Transferable beta/gamma (β/γ) contamination	
	Avg. DF [a]	Percent Removed [b]	Avg. DF	Percent Removed
Painted carbon steel walls	5.06	80.2	9.00	88.9
Unpainted carbon steel walls and ceiling	8.32	88.0	4.75	78.9
Painted Equipment	20.36	95.1	6.90	85.5
Epoxy coated concrete floors	6.25	84.0	3.00	66.7
Total for all surfaces [c]	**6.68**	**85.0**	**5.55**	**82.0**

[a] Decontamination factors (DF) = initial contamination/final contamination. Contamination results were reported in dpm/100 cm^2.
[b] Percent contamination removed = 100 * (1-1/DF)
[c] DFs were not measured for the baseline (steam vacuum cleaning technology). However, discussions with field personnel experienced with the equipment indicate comparable DFs can be expected.

Contamination decreased from an average transferable alpha contamination level of 2,044 dpm/100 cm^2 with a maximum level of 60,000 dpm/100 cm^2 to an average of 417 dpm/100 cm^2 with a maximum contamination level of 10,000 dpm/100 cm^2. In over one-third of all survey locations, the alpha transferable contamination levels were reduced to less than the survey instrument's Minimum Detectable Activity (MDA). Beta transferable contamination was decreased from an average level of 5,162 dpm/100 cm^2 with a maximum level of 40,000 dpm/100 cm^2 to an average of 1,384 dpm/100 cm^2 with a maximum contamination level of 12,000 dpm/100 cm^2 beta. In over two-thirds of all survey locations, the beta transferable contamination levels were reduced to less than the survey instrument's MDA. This decrease in contamination levels however, did not result in a change in radiological postings as future work planned in the area made reduced postings impractical at the present time.

Table 4 compares the key performance indicators of the baseline and alternative technologies that were assessed during the demonstration.

Table 4. Comparison of key performance indicators of cleaning technologies

	Steam Vacuum Cleaning Technology (baseline)[a]	ALARA™ 1146 Strippable Coating (alternative)
Total area included in demonstration	264.51 ft^2	2845 ft^2 1555 ft^2 removed, remaining left in place as a fixative
Work surfaces	Segmented tank flats.	Epoxy coated concrete floor, painted and unpainted metal wall and ceiling. Also some metal equipment.

[a] Data taken from ITSR, *Steam Vacuum Cleaning Technology* for the short wall cleaning tool only.

	Steam Vacuum Cleaning Technology (baseline)[a]	ALARA™ 1146 Strippable Coating (alternative)
Required personnel	Three person crew Single full-time HP	Three person crew Single ¼-time HP
Set-up time (man hrs)	45 (equipment prep only)[b] 41 (includes training and mobilization)	2.25
Productivity (ft^2/man-h[c])	135.6	186.6 (application) 465.0 (removal) 133.1 (overall productivity)
Total volume cleaning media used during demonstration	91.2 gal water	70 gal strippable coating (14 five-gallon buckets)
Water usage (gal/ft^2)	0.34	0.003
Utilities	Vacuum pump: 480V, 15A, 3 phase Control Unit: 480V, 60A, 3 phase Separator: 110V, 6A, single phase Water: 30-40 psig at 3 gal/min	Spray applicator: 110V
Primary waste generated	Contaminated liquid waste	Contaminated solid waste
Secondary waste generated [d]	Vacuum hoses HEPA filter Disposable PPE	Plastic sleeving for hose Empty ALARA™ 1146 buckets Rags (for cleanup of equipment) Spray gun (contaminated) Disposable PPE
Radiological survey of primary waste stream	Not measured	Highest survey reading of cured coating as removed from surfaces (as gross contamination) 20,000 α dpm/100 cm^2 30,000 β/γ dpm/100 cm^2
Airborne contamination	Virtually eliminated when the system is used with the steam vacuum cleaning heads.	Job specific air samples were collected every 15 min during coating removal. No observable increase in airborne contamination was noted.

[a] Data taken from ITSR, *Steam Vacuum Cleaning Technology* for the short wall cleaning tool only.
[b] Data collected from use at SRS.
[c] Includes only actual time in cleaning surfaces (baseline) or applying and removing coating (ALARA™). Does not include preparation of the area or decontamination of the equipment.
[d] Not all waste generated will be radioactively contaminated. The spray applicator and strippable coating buckets were kept in a non-contaminated area during use, therefore, all waste associated with these items would be non-contaminated.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The baseline technology that competes with the ALARA™ 1146 strippable coating is a steam vacuum cleaning technology. The baseline technology produces a large amount of liquid waste that must be contained and transported to a second facility at SRS for processing. The strippable coating produces a minimal amount of liquid waste, and the solid waste generated is easily disposed of.

Another competing approach is manual wiping and cleaning. The advantage of this approach is its lower cost compared to other technologies. However, the following are disadvantages of manual wipe and clean.

- Increased exposure of personnel to contamination. The use of the ALARA™ 1146 strippable coating allows D&D personnel to minimize exposure by fast application and removal times. In addition, fewer personnel would need to be involved to decontaminate a large area using the strippable coating versus manual cleaning.

- Potential of cross contamination as a result of improper technique.

Technology Applicability

The ALARA™ 1146 strippable coating is a fully mature and commercially available technology designed for the decontamination of surfaces, which have transferable (non-fixed) contamination. Although the ALARA™ 1146 was demonstrated at SRS mostly on large flat surfaces (walls, floors, etc.), the coating is effective in decontaminating components such as glove boxes, hand tools, casks, reactor headstands, reactor coolant pumps, reactor vessel studs, and underwater lights.

There are two versions of the ALARA™ 1146 strippable coating product.

Cavity Decon Yellow. Manufactured in compliance with ANSI N101.4 and ASTM D3843, this coating is typically used in reactor cavity decontamination during outages.

Strippable Blue. This coating is manufactured for non-reactor cavity decontamination activities where product certification is not required. *The formulations are the same; however, this product was not certified for compliance with ANSI and ASTM.*

Other potential DOE or commercial nuclear applications include the use of the ALARA™ 1146 strippable coating to protect clean surfaces so that they will not become contaminated. It can be used to cover clean equipment and scaffolding prior to use in a contaminated area. This coating can also be used to lock down or fix contamination on surfaces for long periods of time. Previous assessments performed at both SRS (FIU-HCET, 2000 [draft]) and Florida International University (FIU-HCET, 1999) have shown the ALARA™ 1146 strippable coating to be both durable and easy to remove after long periods (i.e., 180 days). See Appendix B for additional information on strippable coating durability testing.

Patents/Commercialization/Sponsor

ALARA™ 1146 strippable coatings are manufactured by Carboline® of St. Louis, Missouri. Williams Power Corporation is the exclusive vendor of the ALARA™ 1146 product, from which it can be purchased. The product is protected in the United States under patents and trademarks. No permits were required to demonstrate the ALARA™ 1146 strippable coating at SRS.

SECTION 5
COST

Methodology

This cost analysis compares the ALARA™ 1146 strippable coating technology with the baseline steam vacuum cleaning technology. These two comparable technologies remove surface contamination. The strippable coating technology was demonstrated at the DOE-SRS and the baseline technology was evaluated using historical data from an Innovative Technology Summary Report titled, Steam Vacuum Cleaning Technology, OST Reference #1780. The steam vacuum cleaning technology was demonstrated at the Fernald Environmental Management Project - Building 1A, Cincinnati, Ohio. Only applicable portions of the report were used, e.g., capital equipment cost, productivity data for the short wall cleaning tool, and equipment decontamination (cleanup).

This analysis presents realistic estimates that represent actual deactivation work at the Savannah River Site. The site demonstration of the alternative technology was based on the strippable coating material being applied to and removed from 1555 ft^2 of surface area. Some adjustments of the raw data were made, but only those adjustments that would not distort the fundamental elements of the observed data. Adjustments are described in later portions of the analysis and in Appendix D.

The following cost elements were identified from the Army Corps of Engineers Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS) as being applicable to the technology demonstration:

- Mobilization
- Decontamination & Decommissioning
- Personal Protective Equipment
- Waste Disposal
- Demobilization

Mobilization costs include transporting the technology equipment to the demonstration site, preparation of the temporary work area, and a checkout or field test of the equipment.

Decontamination includes all direct and indirect activities associated with decontaminating the area, equipment repositioning, and troubleshooting.

Personal Protective Equipment (PPE) costs are included in this demonstration. For the alternative technology, each participant had two PPE changes per day. For the baseline technology, each participant had three PPE changes for the entire job. In the Appendix D tables, PPE charges were rolled into the Decontamination & Decommissioning cost element.

Waste disposal includes both solid and liquid waste. The alternative technology generates a solid waste: the baseline technology generates a contaminated liquid waste. Cost for disposal of the two waste types is based on prevailing waste disposal rates at SRS. Solid waste is disposed of at a cost of $106 per cubic foot. Liquid waste is processed at an average cost of $1.83 per gallon with an additional $1,000 sampling/testing fee.

Demobilization includes cleanup of the temporary work area, technology equipment decontamination (or cleanup), and removal of the equipment from the demonstration site.

Cost Analysis

Data were collected during the demonstration for each of the cost elements. Time to complete a task associated with the alternative technology was recorded. Labor hours were multiplied by a work group's collective charge rate. As applicable, equipment and material cost was added to labor cost. Unit costs were determined based on the square feet of surface area that was decontaminated. For the baseline technology, the unit cost calculation was supported by data from the Steam Vacuum Cleaning Technology demonstration.

Labor rates used in the alternative technology analysis were those in effect for the SRS site labor agreement. Crew size for the ALARA™ 1146 technology varied between two and three mechanics and a Health Protection technician. Crew size for the baseline technology was based on recorded data from the Steam Vacuum Cleaning Technology demonstration, and SRS labor rates were applied to provide for an equivalent cost comparison. For both the alternative and baseline technologies, costs for personal protective equipment and waste disposal were provided by SRS. For the alternative technology case, mobilization and demobilization costs were based on field data recorded during the demonstration. For the baseline technology, mobilization costs were based on data collected at SRS and demobilization costs were extracted from the Steam Vacuum Cleaning Technology ITSR. Indirect costs were omitted from the analysis, since overhead rates can vary greatly between contractors. Engineering, quality assurance, administrative costs, and taxes were also omitted from the analysis.

Capital equipment costs for the alternative and baseline technologies are based on the cost of ownership. The cost of the strippable coating equipment package is $4,950. The cost of shipping the equipment was included in this capital equipment cost. Since no information was available to definitively determine the projected time of use per year, the following plausible assumptions were made to calculate an equipment unit rate: 1) the expected useful life of the strippable coating equipment package is five years; 2) the equipment is operated eight hours per day, five days a week, for 26 weeks a year. Based on these assumptions, the extended equipment cost per hour of operation would be approximately $0.95/hour [$4950 / (8hrs/d x 5d/wk x 26wk/yr x 5yrs)]. The steam vacuum cleaning technology equipment unit rate is $14/hour. This value includes the capital cost of the equipment and an allowance for maintenance over the equipment's 15-year life. This unit rate was extracted from the Steam Vacuum Cleaning Technology ITSR. At the Savannah River Site, steam vacuum cleaning equipment is site owned and located; therefore, shipping costs were not included in the cost analysis for the baseline decontamination.

Approximately 2845 ft^2 of ALARA™ 1146 strippable coating was applied during the demonstration; however, not all of this was removed, some was left on as a fixative. Since only 1555 ft^2 were stripped (removed) during the demonstration, the unit production rate used for the cost analysis was based on a job size of 1555 ft^2. Data for the Steam Vacuum Cleaning system was handled similarly. For fixed cost elements (which are independent of the quantity of decontamination work), costs were calculated as lump sum costs instead of unit costs. Unit cost elements (which are dependent on the quantity of decontamination work) were based on the amount of decontamination performed.

A comparison of the variable cost elements is shown in Table 5. The mobilization and demobilization costs (the fixed costs) are not included in the unit costs. Decontamination, personal protective equipment, and waste disposal costs are combined for each technology and expressed on a unit cost basis ($/$ft^2$). On a purely unit cost basis, the baseline technology is less expensive. Appendix D tables are provided as references for the raw data in support of the unit cost determinations.

Table 5. Summary Unit Cost Comparison

Strippable Coating (Alternative)			Steam Vacuum Cleaning Technology (Baseline)		
Cost Element	Unit Cost	Production Rate	Cost Element	Unit Cost	Production Rate
Decontamination (incl. PPE) and Waste Disposal	$4.83/ft^2	133.1 ft^2/h	Decontamination (incl. PPE) and Waste Disposal	$2.74/ft^2	135.6 ft^2/h

Cost Comparison

Figure 5 is a cost comparison for the alternative and baseline technologies. The columns represent costs from Tables D.1 and D.2. The columns have been broken down by cost element. PPE costs are included in the Decontamination cost element.

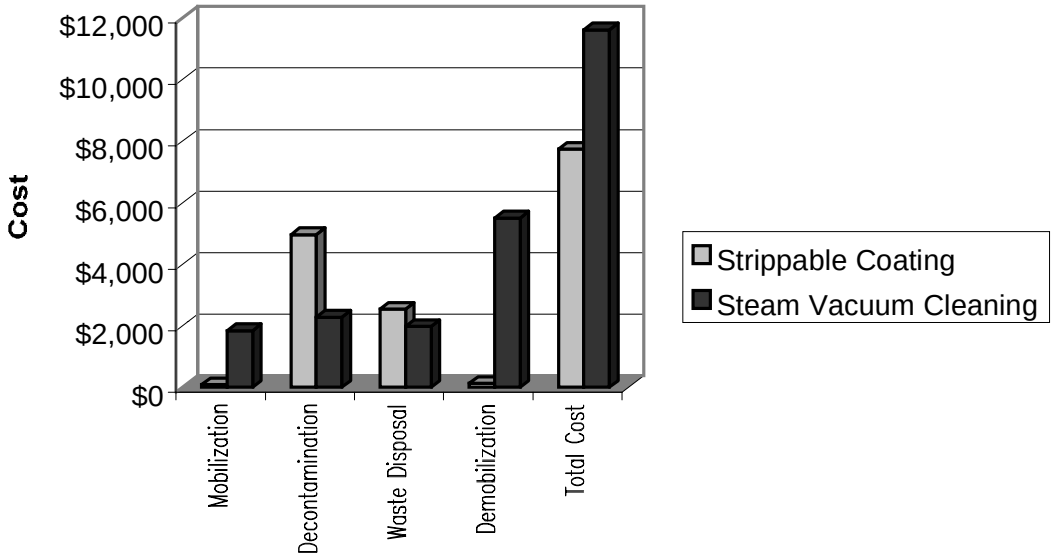


Figure 5. Alternative Technology vs Baseline Technology Cost Summary

It is immediately apparent that the fixed costs (Mobilization and Demobilization costs) for the steam vacuum cleaning technology are much greater than those same costs for the ALARA™ 1146 strippable coating. When combined, the decontamination (including PPE) and waste disposal costs for the ALARA™ 1146 strippable coating are greater than the decontamination (including PPE) and waste disposal costs for the steam vacuum cleaning technology. The result is a higher unit cost ($4.83/ft^2) for the alternative technology than for the baseline technology ($2.74/ft^2).

This data yields a situation where the alternative technology (the ALARA™ 1146 strippable coating) is the technology of choice for smaller area decontamination jobs where very low mobilization and demobilization costs offset the higher unit costs. As a decontamination job becomes larger, the lower unit costs of the baseline technology (the steam vacuum cleaning technology) will compensate for its higher fixed costs, and the baseline technology will become the preferred technology. This “crossover” or breakeven point is 3408 ft^2. The breakeven point is illustrated in Figure 6.

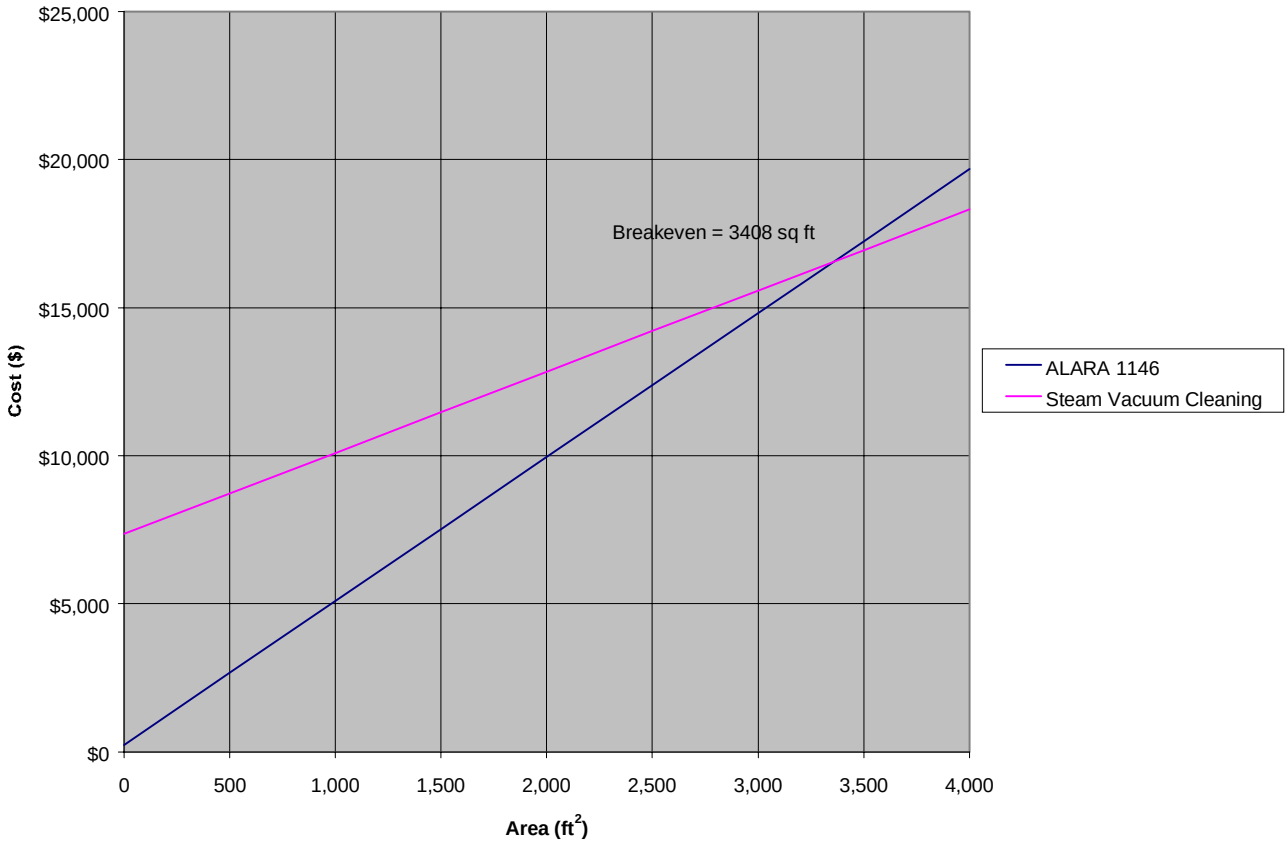


Figure 6. Break-Even Graph for Strippable Coating Technology Demonstration

Cost Conclusions

- For the decontamination job performed as part of the 321-M LSDDP, the ALARA™ 1146 strippable coating offers a 33% cost savings over the baseline Steam Vacuum Cleaning Technology. A total of 1555 ft^2 of surface area was cleaned for the demonstration.

- For relatively smaller (<3400 ft^2), concrete and metal surface decontamination jobs, the ALARA™ 1146 strippable coating is the preferred decontamination method. As a cleanup job grows in size, the lower unit cost of the steam vacuum cleaning technology will shift the cost advantage in favor of this technique.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Although there were no site–specific regulatory or permitting issues concerning the ALARA™ 1146 demonstration at SRS, the following general safety and health regulations should be considered in applying the ALARA™ 1146 strippable coating by spray applicator:

Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910

1910.94	Ventilation
1910.134	Respiratory protection
1910.269	Electric power generation, transmission, and distribution

OSHA 29 CFR 1926

1926.57	Ventilation
1926.103	Respiratory protection
1926.302	Power-operated hand tools

There are no Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or other regulatory considerations related to this technology.

Safety, Risks, Benefits, and Community Reaction

The application of the ALARA™ 1146 strippable coating can pose a health hazard to workers by the inhalation of overspray. Therefore, the vendor recommends the use of airline respirators during spray application of their product. On the positive side, the use of the ALARA™ 1146 substantially reduces levels of surface contamination and reduces the worker exposure to these health hazards.

The main benefit of the ALARA™ 1146 strippable coating is that the waste product is disposed of as a solid waste, thus minimizing liquid waste which may not be able to be processed at the facility being deactivated. A further benefit is that the ALARA™ 1146 entraps contaminants in the matrix of the solid waste, eliminating the chance that the contaminants could become airborne during the handling and packaging of the waste material.

The use of the ALARA™ 1146 strippable coating instead of a steam vacuum cleaning technology should have no potential socioeconomic impacts. The community perspective would likely be positive since it eliminates the chance for spills due to transporting contaminated liquid waste from the facility being deactivated to a second facility for processing.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The ALARA™ 1146 strippable coating is a fully developed and commercially available technology. The product can be purchased in one-gallon and five-gallon containers and can be stored for up to one year.

The following items should be considered when selecting the ALARA™ 1146 as a decontamination or fixative technology:

- While the product is easily applied by standard spray paint equipment, it tends to run down vertical surfaces if applied too thick. Several thinner coats are recommended.
- Manufacturer recommends the spray method of application for best performance. The force of the spray assists the coating in migrating into the surface micro-voids.
- Use an airless spray pump that meets the minimum requirements listed in Section 2. A pump capable of operating without being overloaded, during a work shift, will assure maximum efficiency.
- Thoroughly mix the strippable coating product with an electric mixer prior to spray application. Strain the coating using a fine wire screen or paint strainer to remove partially dried particles and lumps.
- Routinely clean the pump filter during the work shift to remove any collection of partially dried particles.

Technology Limitations and Needs for Future Development

The ALARA™ 1146 strippable coating would benefit from the following design improvements:

- A drying time of less than 24 hours would potentially improve worker productivity.

Technology Selection Considerations

The ALARA™ 1146 strippable coating is an effective product for the removal of surface contamination. The use of strippable coatings is especially applicable for facilities with a need to minimize the amount of liquid waste generated during decontamination activities.

APPENDIX A
REFERENCES

Hemispheric Center for Environmental Technology (FIU-HCET). 1998. *Assessment of Strippable Coatings for Decontamination and Decommissioning, Year-end Report*. Prepared for the U.S. Department of Energy, January.

Hemispheric Center for Environmental Technology (FIU-HCET). 1999. *Assessment of Strippable Coatings for Decontamination and Decommissioning, Final Report*. Prepared for the U.S. Department of Energy, January.

Hemispheric Center for Environmental Technology. 2000. *Deactivation and Decommissioning Technology Assessment Program*. Prepared for the U.S. Department of Energy, draft January.

U.S. Army Corps of Engineers (USACE). 1996. *Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary.* Washington, D.C.: USACE.

Fernald Large-Scale Demonstration Project. 1999. *Steam Vacuum Cleaning Technology*. DOE/EM-0416, Prepared for the Department of Energy, May.

Westinghouse Savannah River Company. 1999. *321-M Large Scale Demonstration and Deployment Project, Demonstration Test Plan, ALARA™ 1146 Cavity Decon Strippable Coating*, May.

APPENDIX B
SIDE-BY-SIDE COMPARISON OF MULTIPLE STRIPPABLE COATINGS

FIU-HCET was commissioned by DOE-OST, to identify and assess potential strippable coatings for use by nuclear industries. Assessments of candidate strippable coatings were performed both at FIU-HCET and at the SRS. The evaluation performed at FIU-HCET included testing the physical characteristics of each coating as well as the ease of applying and removing each product. (FIU-HCET, 1998 and FIU-HCET, 1999) The assessment performed at SRS, by WSRC personnel, included a side-by-side demonstration of six commercially available strippable coatings under radiologically contaminated, comparable field conditions. These six coatings were evaluated for decontamination ability, durability, and application and removal difficulties The assessment was a precursor to the actual full-scale demonstration at 321-M, and based on the best match of product characteristics and facility problem set, ALARA 1146 was selected for demonstration. This section summarizes the results of the assessment performed at SRS.

SRS FACILITY

The 321-M Fuel Fabrication Facility at SRS was built in the 1950s to manufacture fuel tubes for the SRS production reactors. Approximately 9,000 ft^2 inside the facility have been contaminated with Highly Enriched Uranium (HEU). The following areas were included in the side-by-side testing of the strippable coatings:

- **Casting Furnace Enclosures**. Located in the Casting Room, these enclosures are made of painted carbon steel, plexiglass, and concrete. Pre-assessment transferable contamination levels ranged from 0 to 100,000 α dpm/100 cm^2 with the average contamination level at 3,600 α dpm/100 cm^2. A total of 216 ft^2 was used in the strippable coating assessment.

- **Angle-Iron Racks**. Located in the Log Storage Room within the Machining Room, these racks are made of painted carbon and stainless steel. Pre-assessment transferable contamination levels ranged from 5,000 to 60,000 α dpm/100 cm^2 and from 5,000 to 60,000 β/γ dpm/100 cm^2. A total of 56 ft^2 was used in the strippable coating assessment.
- **Scrap Rack Carts**. Located in the Casting Room, these containers are made of painted carbon steel. Pre-assessment transferable contamination levels ranged from 2,000 to 5,000 α dpm/100 cm^2 in the interior and from 800 to 2,000 α dpm/100 cm^2 on the exterior. A total of 8 ft^2 was used in the strippable coating assessment.
- **Log Storage Room Wall**. Located in the Log Storage Room, the walls are painted carbon steel. (These walls were also used for the durability testing.) Pre-assessment transferable contamination levels ranged from 53 to 181 α dpm/100 cm^2 with the average contamination level at 110 α dpm/100 cm^2. A total of 180 ft^2 was used in the strippable coating assessment

Assessment Data Collection

Prior to application of the strippable coatings to the test areas described above, pre-assessment radiological surveys were performed to determine initial surface contamination levels. Each strippable coating was then applied using a spray applicator following the manufacturer's recommendations including wet film thickness. The application rate was calculated for each strippable coating. A standard cure time of 24 hours was allowed before attempting to remove the coatings. Each strippable coating was then removed, and the removal rate and ease of removal were recorded. Post-assessment radiological surveys were performed to determine the final surface contamination levels and to calculate the decontamination factors and percent removal for each strippable coating. Data on coverage, application, removal, waste, costs, etc. were collected to evaluate overall performance of each coating.

Durability of several of the strippable coatings was also determined by applying the coating to sections of the Log Storage Room wall and allowing the coating to remain in place for up to 180 days. One section for each strippable coating was then removed at 15, 30, 60, 90, and 180-day intervals. At each interval, the coatings were evaluated for any changes in their physical properties (e.g., color, appearance), fixative duration, ease of removal, and decontamination factors. Only those strippable coatings that were recommended by the vendor for use as a fixative were included in the durability testing. PENTEK-604 and JDL #GP-RDM were not included in the durability testing for this reason.

Technologies Demonstrated

Descriptions of the six strippable coatings in the SRS demonstration include:

- **ALARA™ 1146**. Sold by Williams Power Corp., this coating is a water-borne vinyl free of solvents and toxic materials. It has a low odor and does not contain chlorides. This product comes in two colors, blue for routine use and yellow for cavity decontamination. The yellow ALARA™ 1146 has been certified for use in reactor outages. The cost of this product is $96/gal.

- **JDL #GP-RDM**. Sold by FRHAM Safety Products, Inc., this coating is water-based, non-toxic, and contains no volatile organic compounds or heavy metals. In the container JDL #GP-RDM is milky white in appearance and after application it turns clear, indicating that the coating is dry and ready to be removed. The cost of this product is $53.50/gal.

- **TechSol 8001**. Sold by Technical Solutions, Inc., this coating is a non-hazardous and water-based reinforced peelable coating. A self-adhesive reinforcement is applied first, and the coating is applied over the reinforcement. This material is classified as temporary durability; thus, it may be peeled in a short period of time. TechSol 8001 is white, has the consistency of paint, and a slight cherry scent. The cost of this product with the reinforced mesh is $98/gal.

- **TechSol 8002**. Sold by Technical Solutions, Inc., this coating is a non-hazardous and water-based, and peelable coating similar to the TechSol 8001 but without the reinforcement. TechSol 8002 is used in the removal of surface contaminants such as alpha and beta radiation and can remove some oxidized metals. TechSol 8002 is white, has the consistency of paint, and a slight cherry scent. The cost of this product is $45/gal.

- **PENTEK-604**. Sold by Pentek, Inc., this coating is self-releasing and suitable for decontamination of relatively smooth and flat metal as well as other non-porous surfaces. PENTEK-604 is a clear, thick viscous solution with a honey-like odor. As the product dries, it flakes off the substrate and can be removed by vacuuming. If any material still adheres to the surface, a light scraping with a dull-edge putty knife will dislodge. The cost of this product is $119.60/gal.

- **Stripcoat TLC Free.** Sold by Bartlett Services, Inc., Stripcoat TLC Free is a one-component, water-based coating. The material is non-hazardous, non-toxic, and contains no volatile organic compounds. This product is yellow and has a thick consistency. The cost of this product is $84/gal.

RESULTS

Results of the strippable coating technology assessment at the SRS 321-M facility are summarized in Tables B-1 to B-3, which follow.

Table B-1. Decontamination results

Strippable Coating Product	Average Decontamination Factor	Average Percent Contaminant Removal (%)
ALARA™ 1146	11.36	81.40
JDL #GP-RDM	3.80	71.64
Tech Sol 8001	9.50	64.48
Tech Sol 8002	6.07	72.88
PENTEK-604	NA [a]	NA
Stripcoat TLC Free	3.16	67.07

Note a: Pentek-604 could not be removed from some substrates, and decontamination ability could not be measured.

Table B-2. Comparison of strippable coating results

Strippable Coating Product	Average Application Rate (ft^2/min)	Coverage (gal/ft^2)	Removal Rate (ft^2/min)	Waste Generated (lb/ft^2)	Calculated Cost ($/$ft^2$)
ALARA™ 1146	2.37	0.05	1.93	1.25	4.97
JDL #GP-RDM	1.38	0.19	1.72	1.95	10.00
Tech Sol 8001	0.77	0.13	1.38	1.22	12.69
Tech Sol 8002	5.90	0.05	1.54	0.52	2.05
PENTEK-604	4.00	0.02	NA [a]	NA	1.87
Stripcoat TLC Free	2.16	0.05	4.58	1.18	4.50

Note a: Pentek-604 could not be removed from some substrates, and many of the results could not be measured.

Table B-3. Durability test results – decontamination factors

Interval (day)	ALARA™ 1146	JDL #GP-RDM	Tech Sol 8001	Tech Sol 8002	Stripcoat TLC Free
1	9.10	4.80	--- [a]	---	---
15	9.32	5.25	3.09	5.04	1.84
30	8.76	11.57	2.81	2.22	1.55
60	7.57	11.00	8.64	2.94	3.10
90	5.34	7.08	2.52	4.59	3.54
180	---	---	1.26	1.05	2.24

Note a: Dashes indicate that the final radiological survey results were higher than initial results.

Summaries of the performance for each strippable coating are:

1. **ALARA™ 1146**. Exhibited a negligible amount of running or dripping and was relatively easy to apply. When applied to vertical sections, it has a tendency to run after the second coat, but adhered well to angled surfaces. Once cured, ALARA™ 1146 had a smooth finish with no observable blistering or cracking. The removal required minimal work and the material was removed in large strips. There were no problems encountered during the application or removal processes.

2. **JDL #GP-RDM**. Exhibited running and formed a puddle on the floor in some locations during application. JDL #GP-RDM was easy to apply, although it did not adhere well to angled surfaces. Once cured, JDL #GP-RDM had minimal blistering and no cracking; however, it separated from the surface and curled at corners or along edges. The removal required minimal work and was removed in large strips.

3. **Tech Sol 8001**. Exhibited very little running and was easy to apply. The mesh helped prevent dripping initially, but running occurred after the second layer. The mesh did not always adhere to the wall well. Once cured, Tech Sol 8001 had a smooth finish with no observable blistering or cracking. Tech Sol 8001 was removed in large strips fairly easily with the mesh, however, part of the mesh remained on the wall after removal.

4. **Tech Sol 8002**. Exhibited running on vertical surfaces, but was rather easy to apply. Once cured, Tech Sol 8002 had a smooth finish, but curled at corners or along edges. Tech Sol 8002 was difficult to remove where the strippable coating was thinner.

5. **PENTEK-604**. This product was diluted 1:1 with water based on the recommendation of the vendor. This was performed to allow the strippable coating to be applied by spray applicator. However, diluting it made it very runny and difficult to apply. Once cured, Pentek-604 exhibited dense blistering, but no cracking. Pentek-604 did not self-strip and was very hard to remove. Only an average of 70% was removable; therefore, removal rate, waste generated, and decontamination factors could not be determined.

6. **Stripcoat TLC Free**. Exhibited little running; however, it was difficult to apply. As applied, stripcoat TLC FREE consistently clogged the tip of the spray nozzle, the spray gun filter, the pump, and the hoses. Once cured, Stripcoat TLC FREE had medium blistering and no cracking. The removal required minimal work and the material was removed in large strips; however, scoring with a razor was needed to remove the coating.

All except one of the strippable coatings included in this assessment were effective in removing surface contamination from vertical and horizontal metal surfaces. The PENTEK-604, diluted to make application by spray applicator easier, did not self-release as advertised by the vendor and was very difficult to remove manually. Performance of the strippable coatings varied by product including the application thickness and method, ease of removal, and decontamination ability. In choosing a strippable coating for a D&D project, all performance measurements should be considered.

The decision was made, based on the results of this assessment and the needs of the deactivation project, to further demonstrate the ALARA™ 1146 strippable coating as part of the SRS LSDDP. The demonstration was performed in May 1999, and the results are presented in the main body of this report.

APPENDIX C
RADIOLOGICAL DATA

This Appendix provides additional details concerning the radiological surveys performed both prior to and after the demonstration of the ALARA™ 1146 strippable coating in the 321-M facility.

		Transferable α Contamination dpm/100 cm^2				Transferable β/γ Contamination dpm/100 cm^2			
Surface	**Survey Point**	**Before**	**After**	**DF[a]**	**Percent Removed[b]**	**Before**	**After**	**DF**	**Percent Removed**
Log Storage Room									
Wall	120	36	<20[c]	1.80		<200 [3]	<200	-	
Wall	121	47	25	1.88		<200	<200	-	
Wall	122	20	<20	-		<1,000	<200	-	
Wall	123	400	37	10.81		<200	<200	-	
Wall	124	<20	<20	-		<200	<200	-	
Wall	125	<20	<20	-		<200	<200	-	
Avg. for painted carbon steel				**3.87**	**74.2**			**NA**	**NA**
Machining Room									
Wall	1	24	<20	1.20		<200	<200	-	
Wall	2	82	63	1.30		<200	<200	-	
Wall	3	156	69	2.26		<200	<200	-	
Wall	4	82	87	-		<200	<200	-	
Wall	5	55	<20	2.75		<200	<200	-	
Wall	6	165	41	4.02		<200	<200	-	
Wall	7	48	28	1.71		<200	<200	-	
Wall	8	98	20	4.90		<200	<200	-	
Wall	9	31	41	-		<200	<200	-	
Wall	10	70	<20	3.50		<200	<200	-	
Wall	11	40	<20	2.00		<200	<200	-	
Wall	12	42	<20	2.10		<200	<200	-	
Wall	13	39	<20	1.95		<200	<200	-	
Wall	14	26	<20	1.30		<200	<200	-	
Wall	15	20	<20	-		<200	<200	-	
Wall	16	31	<20	1.55		<200	<200	-	
Wall	17	107	<20	5.35		<200	<200	-	
Wall	18	300	36	8.33		<1,000	<200	-	
Wall	19	38	<20	1.90		<200	<200	-	
Wall	20	139	32	4.34		<200	<200	-	
Wall	21	68	<20	3.40		<200	<200	-	
Wall	22	50	<20	2.50		<200	<200	-	
Wall	23	52	37	1.41		<200	<200	-	
Wall	24	<20	<20	-		<200	<200	-	
Wall	25	20	21	-		<200	<200	-	
Wall	26	20	<20	-		<200	<200	-	
Wall	27	<20	23	-		<200	<200	-	

[a] Decontamination Factor (DF) = initial contamination/final contamination
[b] Percent (%) contamination recovered = (initial – final)/initial * 100
[c] Less than values were treated as absolute value of number in calculations.

		Transferable α Contamination dpm/100 cm^2				Transferable β/γ Contamination dpm/100 cm^2			
Surface	**Survey Point**	**Before**	**After**	**DF[a]**	**Percent Removed[b]**	**Before**	**After**	**DF**	**Percent Removed**
Wall	28	<20	35	-		<200	<200	-	
Wall	29	<20	<20	-		<200	<200	-	
Wall	30	132	<20	6.60		<200	<200	-	
Wall	31	77	<20	3.85		<200	<200	-	
Wall	32	70	30	2.33		<200	<200	-	
Wall	33	<20	<20	-		<200	<200	-	
Wall	34	<20	25	-		<200	<200	-	
Wall	35	26	400	-		<200	1,000	-	
Wall	36	400	32	12.50		1,000	<200	5.00	
Wall	37	98	35	2.80		<200	1,000	-	
Wall	38	1,400	800	1.75		2,000	<200	10.00	
Wall	39	123	<20	6.15		<200	<200	-	
Wall	40	61	30	2.03		<200	<200	-	
Wall	41	52	43	1.21		<200	<200	-	
Wall	42	38	<20	1.90		<200	<200	-	
Wall	43	54	30	1.80		<200	<200	-	
Wall	44	93	28	3.32		<200	<200	-	
Wall	45	227	62	3.66		<200	<200	-	
Wall	46	107	64	1.67		<200	<200	-	
Wall	47	800	172	4.65		<1,000	<200	-	
Wall	48	208	<20	10.40		<200	<200	-	
Wall	49	64	103	-		<200	<200	-	
Wall	50	77	41	1.88		<200	<200	-	
Wall	51	75	32	2.34		<200	<200	-	
Wall	52	139	202	-		<200	<200	-	
Wall	53	22	<20	1.10		<200	<200	-	
Wall	54	<20	<20	-		<200	<200	-	
Wall	55	23	138	-		<200	<200	-	
Wall	56	68	2,000	-		<200	3,000	-	
Wall	58	296	25	11.84		<200	<200	-	
Wall	59	200	39	5.13		1,000	<200	5.00	
Wall	60	151	<20	7.55		<200	<200	-	
Wall	63	400	<20	20.00		<1,000	<200	-	
Wall	64	123	<20	6.15		<200	<200	-	
Wall	65	20	<20	-		<200	<200	-	
Wall	66	178	<20	8.90		<200	<200	-	
Wall	67	339	<20	16.95		<200	<200	-	
Wall	68	41	55	-		<200	<200	-	
Wall	69	1,200	20	60.00		1,000	<200	5.00	
Wall	70	236	28	8.43		<200	<200	-	
Wall	71	72	36	2.00		<200	<200	-	
Wall	72	118	36	3.28		<200	<200	-	
Wall	73	600	25	24.00		<1,000	<200	-	
Wall	74	45	27	1.67		<200	<200	-	
Wall	75	45	21	2.14		<200	<200	-	
Wall	76	<20	30	-		<200	<200	-	

		Transferable α Contamination dpm/100 cm^2				Transferable β/γ Contamination dpm/100 cm^2			
Surface	**Survey Point**	**Before**	**After**	**DF[a]**	**Percent Removed[b]**	**Before**	**After**	**DF**	**Percent Removed**
Wall	77	70	25	2.80		<200	<200	-	
Wall	78	<20	30	-		<200	<200	-	
Wall	79	<20	<20	-		<200	<200	-	
Wall	80	52	<20	2.60		<200	<200	-	
Wall	81	22	<20	1.10		<200	<200	-	
Wall	82	58	<20	2.90		<200	<200	-	
Wall	83	<20	<20	-		<200	<200	-	
Wall	84	59	25	2.36		<200	<200	-	
Wall	85	<20	25	-		<200	<200	-	
Wall	86	20	32	-		<200	<200	-	
Wall	87	49	<20	2.45		<200	<200	-	
Wall	88	<20	<20	-		<200	<200	-	
Wall	89	43	23	1.87		<200	<200	-	
Wall	90	<20	28	-		<200	<200	-	
Wall	91	<20	21	-		<200	<200	-	
Wall	92	<20	32	-		<200	<200	-	
Wall	93	50	<20	2.50		<200	<200	-	
Wall	94	50	<20	2.50		<200	<200	-	
Wall	95	<20	<20	-		<200	<200	-	
Wall	96	43	<20	2.15		<200	<200	-	
Wall	97	<20	<20	-		<200	<200	-	
Wall	98	<20	<20	-		<200	<200	-	
Wall	99	<20	<20	-		<200	<200	-	
Wall	100	<20	<20	-		<200	<200	-	
Wall	101	<20	35	-		<200	<200	-	
Wall	102	31	21	1.48		<200	<200	-	
Wall	103	<20	<20	-		<200	<200	-	
Wall	104	151	30	5.03		<200	<200	-	
Wall	105	68	<20	3.40		<200	<200	-	
Wall	106	<20	<20	-		<200	<200	-	
Wall	107	20	<20	-		<200	<200	-	
Wall	108	144	21	6.86		4,000	<200	20.00	
Avg. for painted carbon steel wall				**5.13**	**80.5**			**9.00**	**88.9**
Lathe-Bottom	56A	6,000	1,000	6.00		5,000	2,000	2.50	
Lathe-Top	57	2,400	23	104.35		3,000	<200	15.00	
Equipment	61	98	181	-		<200	<200	-	
Equipment	62	45	48	-		<200	<200	-	
Equipment	116	1,400	1,000	1.40		4,000	1,000	4.00	
Equipment	117	3,200	600	5.33		5,000	<1,000	5.00	
Equipment	118	6,600	2,000	3.30		8,000	1,000	8.00	
Equipment	119	1,400	800	1.75		<200	1,000	-	
Avg. for painted carbon steel equipment				**20.36**	**95.1**			**6.90**	**85.5**
Floor	109	4,800	600	8.00		1,000	<1,000	-	
Floor	110	3,000	400	7.50		<1,000	<1,000	-	
Floor	111	3,000	<200	15.00		3,000	<1,000	3.00	

		Transferable α Contamination dpm/100 cm^2				Transferable β/γ Contamination dpm/100 cm^2			
Surface	**Survey Point**	**Before**	**After**	**DF[a]**	**Percent Removed[b]**	**Before**	**After**	**DF**	**Percent Removed**
Floor	112	2,800	400	7.00		1,000	<1,000	-	
Floor	113	1,800	400	4.50		1,000	<1,000	-	
Floor	114	1,400	400	3.50		1,000	<1,000	-	
Floor	115	1,800	200	9.00		1,000	<1,000	-	
Avg. for painted concrete floor				**7.79**	**87.2**			**3.00**	**66.7**
Casting Room Cooling Hut									
Wall	1	4,000	2,000	2.00		4,000	2,000	2.00	
Wall	2	4,000	600	6.67		4,000	<1,000	4.00	
Wall	3	4,000	500	8.00		4,000	<1,000	4.00	
Wall	4	4,000	600	6.67		6,000	<1,000	6.00	
Wall	5	6,000	800	7.50		6,000	<1,000	6.00	
Ceiling	6	6,000	200	30.00		6,000	<1,000	6.00	
Wall	7	6,000	400	15.00		6,000	<1,000	6.00	
Wall	8	2,000	1,000	2.00		4,000	1,000	4.00	
Wall	9	4,000	2,000	2.00		2,000	3,000	-	
Ceiling	10	12,000	1,000	12.00		20,000	2,000	10.00	
Wall	11	4,000	1,000	4.00		4,000	<1,000	4.00	
Ceiling	12	2,000	2,000	-		4,000	2,000	2.00	
Wall	13	2,000	600	3.33		2,000	<1,000	2.00	
Wall	14	8,000	1,000	8.00		4,000	<1,000	4.00	
Wall	15	8,000	400	20.00		6,000	<1,000	6.00	
Wall	16	10,000	3,000	3.33		10,000	3,000	3.33	
Wall	17	10,000	2,000	5.00		8,000	<1,000	8.00	
Wall	22	60,000	10,000	6.00		40,000	12,000	3.33	
Avg. for unpainted carbon steel				**8.32**	**88.0**			**4.75**	**78.9**
Floor	18	5,000	800	6.25		4,000	<1,000	4.00	
Floor	19	3,000	1,000	3.00		2,000	<1,000	2.00	
Floor	20	4,000	2,000	2.00		<1,000	2,000	-	
Floor	21	6,000	2,000	3.00		3,000	1,000	3.00	
Avg. for painted concrete floor				**3.56**	**71.9**			**3.00**	**66.7**

[a] Decontamination Factor (DF) = initial contamination/final contamination
[b] Percent (%) contamination recovered = (initial – final)/initial * 100
[c] Less than values were treated as absolute value of number in calculations.

APPENDIX D
TECHNOLOGY COST COMPARISON

Introduction

The analysis presents realistic estimates to compare costs between an alternative technology (ALARA™ 1146 strippable coating) and a baseline technology (steam vacuum cleaning). The alternative technology uses a spray on coating to encapsulate the surface contamination. When the coating is stripped from the treated surface, the contaminants are removed. The baseline technology utilizes superheated steam to clean a contaminated surface and a shrouded vacuum to remove the contaminants.

The selected activities being analyzed are grouped in accordance with the Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS), USACE, 1996. The HTRW RA WBS, which was developed by an interagency group, was used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis so that it more realistically reflects a typical commercial application. The general and administrative (G&A) markup costs for the site contractor managing the demonstration are omitted from this analysis. Overhead rates for each DOE site vary in magnitude and in the way they are applied. Decision-makers seeking site-specific costs can apply their site's G&A rate to this analysis without having to first back out the rates used at SRS.

The following assumptions were used as the basis for the alternative and baseline technology cost analysis:

- Oversight engineering, quality assurance, and some administrative cost for the demonstration were not included.
- As applicable, equipment hourly rates for the alternative and baseline pieces of equipment reflect government ownership, and are based on general guidance contained in the Office of Management and Budget's (OMB) Circular No. A-94 for Cost Effectiveness Analysis.
- Some productivity and cost data for the baseline technology, steam vacuum cleaning, based on the Steam Vacuum Cleaning Technology demonstration (Fernald, 1999). Mobilization times, labor rates, and PPE costs were based on SRS numbers.
- Equipment unit rates for the alternative technology are determined based on information recorded in the USACE data collection forms.
- Standard labor rates established by the Savannah River Site for estimating D&D work were used for those portions of work performed by the site's work force.
- The analysis expresses all work on an hourly basis.

MOBILIZATION (WBS 331.01)

Alternative technology
Move Equipment into CA, Setup, Check and Test Equipment**:** SRS labor to move equipment into the CA, setup CA, and test equipment.

Baseline technology
Move Equipment into CA, Setup, Check and Test Equipment**:** SRS data (hours and labor rates) were used for equipment mobilization.

DECONTAMINATION AND DECOMMISSIONING ACTIVITY (WBS 331.17)

Alternative technology
Apply Coating: This activity includes mixing coating, operating sprayer, and spraying the strippable coating onto the contaminated areas. Includes hourly rate cost for spray applicator and cost for 38 gallons of strippable coatings at $96/gal.

Remove Coating: Labor to manually strip/peel off the applied coating and package the solid contaminated waste.

Equipment Cleanup: Labor cost to clean filters, flush equipment with clean water, and general cleanup of equipment. Remove any disposable protective material from equipment.

Don/Removal of Personnel Protective Equipment, (PPE): Don and remove PPE's as required to perform work in a CA. Two changes of PPE per day per person (8 sets total) were used in the calculation.

Baseline technology
Steam/Vacuum Cleaning: Unit cost and production rate for baseline technology are from the Steam Vacuum Cleaning Technology demonstration (Fernald, 1999).

Don/Removal of Personnel Protective Equipment (PPE): Three sets of PPE per worker over the demonstration (12 sets total) were used in the calculation.

WASTE DISPOSAL (WBS 331.18)

Alternative technology
Waste Disposal: Disposal of solid contaminated waste generated by the strippable coating. A total of 24 ft^3 was disposed of at a rate of $106/$ft^3$.

Baseline technology
Waste Disposal: Disposal of the liquid waste generated by the steam vacuum cleaning technology. A total of 537 gals (0.345 gal/ft^2 from Steam Vacuum Cleaning Technology ITSR) at $1.83/gal.

Waste Sample Analysis: SRS cost for sample analysis of $1,000 for liquid quantities over 400 gallons.

DEMOBILIZATION (WBS 331.21)

Alternative technology
Remove Equipment from Radiological Areas: Labor to clear and remove equipment from CA.

Baseline technology
Remove Equipment from Radiological Areas: Labor to decontaminate, clear and remove equipment from CA. Time required to decontaminate the baseline technology is based on the Steam Vacuum Cleaning Technology demonstration.

The details of the cost analysis for the alternative and baseline technologies are summarized in Tables D-1 and D-2.

Table D-1. ALARA™ 1146 Strippable Coating Cost Data

Work Breakdown Structure (WBS)	Unit Costs Hrs = h/Unit of Measure; Rate=$/h; Other=$						Total Quantity (TQ)	Unit of Measure	Total Cost (TC) [1]	Crew	Comments
	Labor		Equipment		Other	Total Unit Cost (TUC)					
	Hrs	Rate	Hrs	Rate		$/SF					
Mobilization (WBS 331.01)			**Subtotal**						$ 92		
Move Equipment into CA, Setup, Check and Test Equipment	1	$ 92.16					1	job	$ 92.16	2 Mechanics, 1 HP Tech.(1/4 time) [2]	
Decontamination & Decommissioning Activity (WBS 331.17)			**Subtotal**						$ 4962		
Apply Coating [3,4,5]	0.00178	$134.49	0.00178	$ 0.95	$3,673.00	$ 2.60	1555	SF	$ 4,047.88	3 Mechanic , HP Tech.(1/4 time)	"Other" is Material Cost. This was a 2.77 h job.
Remove Coating	0.00107	$ 92.16				$ 0.10	1555	SF	$ 153.34	2 Mechanic , HP Tech.(1/4 time)	This was a 1.66 h job..
Don/Removal of Personal Protective Equipment (PPE) [6,7]	1.6	$156.99			$ 129.04	$ 380.22	2	day	$ 760.45	3 Mechanics & 1 HP Tech.	"Other" cost is PPE, $16.13/set. Two changes/day.
Waste Disposal (WBS 331.18)			**Subtotal**						$ 2,544		
Waste Disposal [8]						$ 1.64	1555	SF	$ 2,543.98		24 ft^3 @ $106/$ft^3$
Demobilization WBS (331.21)			**Subtotal**						$ 139		
Equipment Cleanup	1	$ 84.66					1	job	$ 84.66	2 Mechanics	
Remove Equipment from Radiological Areas	0.75	$ 72.33					1	job	$ 54.25	1 Mechanic & 1 HP Tech.	
Total Cost For The Demonstration									$ 7,737		

NOTES

1. TC = TUC X TQ (where TC = total cost, TUC = total unit cost, and TQ = total quantity); SF = ft^2

2. Labor rates are $42.33/hr for Mechanic, $30.00/hr for Health Protection (HP) Technician

3. Unit Cost Calculation: 2.77hr job to apply coating / 1555 SF = .00178 hrs/SF

4. The strippable coating equipment package has an equipment unit rate of $0.95/hour. Reference the Section 5 text.

5. Material cost for ALARA 1146 is $96 / gallon. Seventy (70) gallons of ALARA 1146 were used for the total job. [(1555 SF / 2845 SF) x 70 gallons x $96 / gallon] = $3673

6. Two PPE changes per day. Each person takes on average 6 minutes to don and 6 minutes to remove PPE. [(4 people x 6 m to don) + (4 people x 6 m to remove)] x 2 times = 96 m for one day. 96 minutes = 1.6 hours.

7. Two PPE changes per day. (4 people x 2 changes/day x $16.13 per change) = $129.04

8. [(24 ft^3 of solid waste) x ($106 / ft^3 to disposition)] / 1555 SF = $1.636 / SF to disposition solid waste on a SF basis.

Table D-2. Steam Vacuum Cleaning Technology Cost Data

Work Breakdown Structure (WBS)	Unit Cost Hrs = h/Unit of Measure; Rate=$/h; Other=$						Total Quantity (TQ)	Unit of Measure	Total Cost (TC) [1]	Crew	Comments
	Labor		Equipment		Other	Total Unit Cost (TUC)					
	Hrs	Rate	Hrs	Rate		$/SF					
Mobilization (WBS 331.01)			**Subtotal**						$ 1,850		
Unload, Move Equipment into CA, Setup, Check and Test Equipment [3]	20	$ 92.16	1	$ 6.55			1	job	$ 1,849.75	2 Mechanics, use of Forklift, 1 HP Tech. (1/4 time) [2]	20 hrs is equipment prep time based on data collected at SRS
Decontamination & Decommissioning Activity (WBS 331.17)			**Subtotal**						$ 2,281		
Steam/Vacuum Cleaning [4,5]	0.0074	$134.49	0.0074	$14.00		$ 1.10	1555	SF	$ 1,710.50	3 Mechanic , 1 HP Tech (1/4 time)	Based on 11.5 h job.
Don/Removal of Personnel Protective Equipment (PPE) [6,7]	2.4	$156.99			$ 193.56		1.0	job	$ 570.34	3 Mechanic , 1 HP Tech	"Other Cost" are PPEs, 3 changes/ worker for total job ($16.13/set)
Waste Disposal (WBS 331.18)			**Subtotal**						$ 1,981		
Waste Disposal [8]						$ 0.63	1555	SF	$ 981.21		
Waste Sample Analysis					$1,000.00	$ 1,000.00	1	each	$ 1,000.00		
Demobilization (WBS 331.21)			**Subtotal**						$ 5,504		
Equipment Decon (cleanup) & Remove Equipment from Radiological Area	48	$114.66					1	job	$ 5,503.68	2 Mechanics, 1 HP Tech.	Hours and manpower resources extracted from Steam Vacuum Cleaning ITSR.
Total Cost For The Demonstration									$ 11,615		

NOTES

1. TC = TUC X TQ (where TC = total cost, TUC = total unit cost, and TQ = total quantity); SF = ft^2
2. Labor rates are $42.33/hr for Mechanic, $30.00/hr for Health Protection (HP) Technician.
3. Fork lift is rented from the Portable Equipment Commodity Management Center at SRS for $6.55 / hour.
4. Unit Cost Calculation: 11.5 hr job to steam vacuum clean area / 1555 SF = .0074 hrs/SF
5. The steam vacuum cleaning equipment package has an equipment unit rate of $14.00 / hour (data extracted from Steam Vacuum Cleaning Technology ITSR).
6. Three PPE changes for entire job. Each person takes an average of 6 minutes to don and 6 minutes to remove PPE. [(4 people x 6m to don) + (4 people x 6 m to remove)] x 3 times = 144m for entire job. 144minutes = 2.4 hrs.
7. Three PPE changes for entire job. (4 people x 3 changes/job x $16.13/set) = $193.56
8. [(.345 gallons of liquid waste generated / SF) x ($1.83 processing charge / gallon of liquid waste) = $.631 / SF to process liquid waste generated on a SF basis.

APPENDIX E
ACRONYMS AND ABBREVIATIONS

α	alpha
β	beta
γ	gamma
A	ampere
CFR	Code of Federal Regulations
cm^2	square centimeters
D&D	decontamination and decommissioning
DF	decontamination factor
DOE	Department of Energy
dpm	disintegrations per minute
FIU-HCET	Florida International University, Hemispheric Center for Environmental Technology
ft/ft^2	feet/square feet
gal	gallon
h	hour
HEPA	high efficiency particulate air
HEU	highly enriched uranium
HP	health protection
ID	internal diameter
in.	inch
LSDDP	Large Scale Demonstration and Deployment Project
MDA	minimum detectable activity
min	minute(s)
OSHA	Occupational Safety and Health Administration
OST	Office of Science and Technology
PPE	personal protective equipment
RH	relative humidity
SRS	Savannah River Site
USACE	United States Army Corps of Engineers
WSRC	Westinghouse Savannah River Company
V	volt